

**HSE Approved specifications for fire resistance and  
hygiene of hydraulic fluids for use in machinery and  
equipment in mines**

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# 1. Foreword

This document has been prepared in support of Regulation 8 of the Mines Miscellaneous Health and Safety Provisions Regulations 1995, (the Regulations). The Regulations implement European Council Directive 92/104/EEC (the Extractive Industries Directive) and in particular Part C, Clause 11.3 of the special minimum requirements applicable to underground mineral extracting industries concerning fire-resistant fluids. Regulation 8(1) of the Regulations refers to the use of approved specifications relating to fire resistance and hygiene for hydraulic fluids<sup>1</sup> used at a mine. For the convenience of the reader Regulation 8 is reproduced at Appendix F.

This document includes a minimum requirement for coal mines. It also sets out a methodology by which compliance with Regulation 8 may be achieved by the selection of fire-resistant fluids or by other means based on Risk Assessment. It is concerned principally with fire resistance and hygiene properties, and does not cover other properties of fire-resistant fluids such as corrosion prevention, compatibility with elastomers and other such matters.<sup>2</sup> The document additionally seeks to provide guidance to mine management and to the workforce on the different types of fluids available for use in mines and their properties.

## 2. Scope

This document gives requirements for fire resistant fluids intended for use in all underground mines and gives guidance on achieving a minimum level of safety in their end use application.

The performance requirements set out in certain test specifications in this document are those that have been found to give an adequate level of safety. More information on these requirements and on the properties of fire-resistant fluids can be found in Appendices A to C.

## 3. Fire resistance and hygiene standards

The following sub-sections set out standards for safety based on the test methods identified in Appendices B and C. The approach taken has been to specify a level of performance that would be necessary to provide operational safety where the risks present arise from difficulties of access and egress in underground situations and where sources of ignition are assumed to be present.

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<sup>1</sup> For the purposes of this document “hydraulic fluid” means a fluid used for the transmission of hydrostatic or hydrokinetic mechanical energy. This is the same definition as that given in the Mines Miscellaneous Health and Safety Provisions Regulations 1995

<sup>2</sup>Information on these other properties may be found in documents such as the 7th Luxembourg Report, ISO 12922 and British Coal Specifications 463 and 570.

The standards give the minimum level of performance requirements for UK coal mines (see 3.1) that have been used over many years and therefore proven to be reasonably practicable to comply with (See Regulation 8 at Appendix F). Section 3.1 should also be used where additional hazards such as the presence of flammable<sup>3</sup> atmospheres, flammable dusts or fuel sources additional to and greater than that from the fluid alone are present.

For non-coal mines and where some of the above factors are absent i.e. there are no additional sources of fuel or there are no flammable dusts present or where additional safety measures are in place information is given on the risk assessment procedures to be followed (see 3.2).

For all mines it is necessary to carry out a final risk assessment after considering all of the performance requirements. Wherever practicable fluids that comply with as many of the fire performance requirements as possible should be used.

For all mines the specifications give the minimum standards for hygiene hazards (see 3.3.1) and continuity of properties during use (see 3.3.2). Guidance is also given on environmental assessment (3.3.3)

A flowchart, which is designed to clarify and summarise the process of fire hazard and risk assessment for the selection of a suitable fluid, is presented as Figure 1 on page 14.

For the purpose of the fire hazard and risk assessment process given in this section and in Figure 1, if a decision is made not to undertake any particular test it must be assumed that the fluid has failed the test and, in the case of the spray ignition test, obtained an ignitability index (RI) of less than 25.

### **3.1. Standards for coal mines**

#### **3.1.1 Ignition of flammable vapours - flash point**

When measured by ISO 2592 (the Cleveland open cup flash point test) the flash point of the fluid should exceed 200 °C.

Additional information on this test is given in Section B2.1 of Appendix B.

#### **3.1.2. Spray ignition**

When tested by the method given in ISO 15029 Part 1 (the Hollow cone nozzle method) the fluid should record a “pass”.

When tested by the method given in ISO 15029 Part 2 (the Stabilised flame heat release method) the fluid should record an ignitability index, RI, greater than 25<sup>4</sup>. Additional information on these tests is given in Section B2.2 of Appendix B.

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<sup>3</sup> For the purposes of this Document the term “flammable “ when used in relation to vapours and dusts should be taken to mean that these substances will ignite and have the potential to spread flame.

<sup>4</sup> It is accepted that performance in ISO 15029 Part 1 is not necessarily related to performance in ISO 15029 Part 2, however the value of 25 for RI has been set on the basis of existing experience of testing fluids that have been in widespread use in coal mines. It should be taken as the appropriate level until further information or research indicates that another value is appropriate.

It has been found that a “pass” by the method given in ISO 15029 Part 1 (equivalent to the spray test in British Coal Specification 570) has given an adequate level of safety in UK coal mines and in conjunction with a pass in BS EN ISO 14935 (the Wick test, see 3.1.3 below) continues to be the minimum level of performance required for those mines.

Fluids that have been in widespread use in coal mines have also been found to give an ignitability factor (RI) greater than 25 (see Note 4).

The total enclosure of hydraulic systems in, for example, a cast steel machine casing, so that they are inaccessible to sources of ignition and it is unlikely that fluid will spray into the surrounding atmosphere, has been found to give a safe situation for the use of mineral oil hydraulic fluids in UK coal mines.

The “Stabilised flame heat release” test in ISO 15029 Part 2 should be used for all fluids proposed for use in mines because of the superior level of information it is able to provide for risk assessment.

### **3.1.3. Fluid soaking into absorbent material**

The fluid should record a “pass” when tested according to the method given in BS EN ISO 14935 (the Wick test).

Additional information on this test is given in Section B2.3 of Appendix B.

The total enclosure of hydraulic systems in, for example, a cast steel machine casing, so that they are inaccessible to sources of ignition and unlikely to leak fluid onto other flammable materials has been found to give a safe situation for the use of mineral oil hydraulic fluids in UK coal mines.

### **3.1.4. Ignition by hot surfaces**

In the Manifold Ignition Test given in the document CETOP RP65H: 1994, the fluid should not flash or burn either on the tube or after dripping from the tube. Additional information on this test is given in Section B2.4 of Appendix B.

Where the temperature of surfaces is limited by standards supporting legislation to 150 °C or less, the Manifold Ignition test need not be carried out.

## **3.2 Standards for non-coal mines**

### **3.2.1 Ignition of flammable vapours - flash point**

When measured by ISO 2592 (the Cleveland open cup flash point test) the flash point of the fluid should exceed 200 °C.

Additional information on this test is given in Section B2.1 of Appendix B.

A risk assessment procedure should be used to indicate whether this requirement might be necessary (see Figure1) where:-

- excessive heating of the fluid does not occur, or
- additional safety measures such as fire suppression systems are installed to provide a safe situation, or
- there are no sources of ignition present.

### **3.2.2 Spray ignition**

When tested by the method given in ISO 15029 Part 1 (the Hollow cone nozzle method) the fluid should record a “pass”.

When tested by the method given in ISO 15029 Part 2 (the Stabilised flame heat release method) the fluid should record an ignitability index (RI) greater than 25 (see Note 4 on page 5).

Additional information on these tests is given in Section B2.2 of Appendix B.

The Ignitability Index (RI) which is the primary measure of fire resistance from the “Stabilised flame heat release test” may be used together with two secondary measures, the Flame Length Index (RL) and the Optical Density of Smoke Index (D) in a risk assessment to determine a level of fire resistance appropriate to the operational situation.

The “Stabilised flame heat release” test in ISO 15029 Part 2 should be used for all fluids proposed for use in mines because of the superior level of information it is able to provide for risk assessment.

A risk assessment procedure should be used to indicate whether the requirement for a “pass” by the method given in ISO 15029 Part 1 and an ignitability index (RI) of greater than 25 in the “Stabilised flame heat release test” given in ISO 15029 Part 2 may be necessary (see Figure 1) where:-

- additional safety measures such as fire suppression systems are installed to provide a safe situation, or
- hydraulic systems are totally enclosed and inaccessible to sources of ignition, (e.g. the total enclosure of hydraulic systems in a cast steel machine casing, which has been found to give a safe situation for the use of mineral oil hydraulic fluids in UK coal mines), or
- ignition sources have been eliminated.

### **3.2.3 Fluid soaking into absorbent material**

The fluid should record a “pass” when tested according to the method given in BS EN ISO 14935 (the Wick test).

Additional information on this test is given in Section B2.3 of Appendix B.

A risk assessment procedure should be used to indicate whether the requirement to pass the wick test is required (see Figure 1) where:-

- the working environment does not contain flammable dusts or does not involve the use of lagging or similar materials on machines that could absorb fluid, or
- additional safety measures such as fire suppression systems are installed to provide a safe situation, or
- hydraulic systems are totally enclosed and inaccessible to sources of ignition, or
- there are no additional sources of fuel.

### **3.2.4 Ignition by hot surfaces**

In the Manifold Ignition Test given in the document CETOP RP65H: 1994, the fluid should not flash or burn either on the tube or after dripping from the tube.

Additional information on this test is given in Section B2.4 of Appendix B.

A risk assessment procedure should be used to indicate whether this requirement might be necessary (see Figure 1) where:-

- the temperature of surfaces is limited to 150oC or less; or
- additional safety measures such as fire suppression systems are installed to provide a safe situation, or
- where hydraulic systems are totally enclosed and inaccessible to ignition from hot surfaces.

### **3.3 All mines**

#### **3.3.1 Hygiene hazards**

Fire resistant fluids used in all mines should, as a minimum, conform to the requirements of Part IV of “Methods of Testing for Assessing Health Hazards” of the European Commission document “Requirements and Tests applicable to Fire-Resistant Hydraulic Fluids used for Power Transmission and Control (Hydrostatic and Hydrodynamic) Seventh Edition” Document No 4746/10/91 EN (the 7th Luxembourg Report) with respect to oral toxicity, irritation of skin and eyes, inhalation toxicity of aerosols and of thermal decomposition products<sup>5</sup>, and the neurotoxic effects of phosphate esters. In addition all reasonable steps shall be taken to ensure that the fluids do not cause sensitisation or other effects of long term or repeated exposure.

The requirements of Part IV of the 7th Luxembourg Report comprise the minimum amount of information that must be provided for a satisfactory assessment of the hygiene hazards. The appropriate data may be provided by using the tests described in the Report or by the use of information produced to fulfil the regulatory requirements of the Chemicals (Hazard Information and Packaging) Regulations (CHIP) and Control of Substances Hazardous to Health Regulations (COSHH) or the Notification of New Substances Regulations, providing that appropriate correlations exist between the requirements of the Report and the other data. Where the test methods in the 7th Luxembourg Report are not used, the information supplied to demonstrate compliance must be sufficiently comprehensive to show positively how compliance has been achieved. Freedom from toxicity can only be demonstrated by the presence of appropriate data: the absence of data cannot be taken to indicate that toxic effects are not present. In this situation the tests described in the Report should be carried out.

Hygiene hazards and risk assessment are also referred to in Sections 4.3 and 5.

Further information on the tests and requirements of Part IV of the 7th Luxembourg Report and examples of the way in which other information may be used to fulfil these requirements is given in Appendix C.

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<sup>5</sup> These tests are not intended to allow a full assessment of the toxicity of the products of combustion of hydraulic fluids. Further information on this aspect should be sought from the fluid supplier or may be obtained from the results of the tests to ISO 15029 Part 2 (see 3.1.2 and 3.2.2)

### **3.3.2 Continuity of properties.**

Hydraulic fluids used in all mines should continue to meet the safety standards considered necessary from the risk assessment and the appropriate test requirements given in Sections 3 and Figure 1 during the whole of their operational life. Appropriate fluid monitoring and maintenance routines will assist in ensuring that this requirement is met.

### **3.3.3 Environmental assessment**

Consideration should be given to the possible environmental impact of the use of a hydraulic fluid. Guidance on assessing the risks to the environment may be found in Part VI of the 7th Luxembourg Report.

## **4. Identification of hazards**

### **4.1 Fire hazards**

During the preparation of this document certain fire hazards have been identified as being directly related to the use of hydraulic fluids underground and are in addition to the basic underground hazard of difficulty of access and egress caused by confined working areas:-

These fire hazards are:-

- a) the ignition of flammable vapours produced by hydraulic fluid;
- b) the ignition of hydraulic fluids ejected from hydrostatic or hydrodynamic systems in the form of a spray, with the production of smoke, heat, flame and possibly toxic products;
- c) the ignition of hydraulic fluid leaking from hydrostatic or hydrodynamic systems or spilled during transport on to absorbent material such as lagging on machines or flammable dust and the subsequent propagation of fire along the absorbent material;
- d) the ignition of a fluid stream or pool with production of smoke, heat, flame and possibly toxic products.
- e) the ignition of hydraulic fluids when the fire resistance has been reduced by service operation. Examples of this would be the evaporation or separation of the water content for some types of fluid and the breakdown of the chemical composition for other types of fluid (See 3.3.2 and Appendix A4).

Test methods and procedures that may be used to address some of these hazards may be found in Appendix B to this document.

### **4.2 Sources of ignition**

Potential sources of ignition such as sparks, flames, electric arcs, high surface temperatures, acoustic energy, optical radiation and electromagnetic waves have been identified in European Council Directive 92/104/EEC (the Extractive Industries Directive) as being potentially present in underground mines. A list, which should not be taken as exhaustive, of possible situations in which these sources of ignition may occur is given below.

- a) the discharge of static electricity;

- b) stray electric currents or discharges from malfunctioning electricity supply equipment which could produce overheating of surfaces or sparks capable of causing ignition;
- c) friction between moving surfaces or the entrapment of foreign bodies between moving surfaces caused, for example, by failures of mechanical plant, causing localised overheating;
- d) high surface temperatures present in internal combustion engines, braking systems, transmissions or exhausts;
- e) the use of smoking or other materials that may be contraband in some mines;
- f) existing fires caused by the ignition of other flammable materials in the mine.

### **4.3 Hygiene**

The principal hygiene hazards that should be considered in relation to the use of hydraulic fluids in mines have been identified in Part IV of the 7th Luxembourg Report.

These hazards are:

- a) acute oral toxicity;
- b) irritant effect on the skin;
- c) irritant effect on the eye;
- d) inhalation toxicity of the fluid as an aerosol;
- e) inhalation toxicity of thermal decomposition products;
- f) neurotoxic effects of phosphate ester-based fluids.

The 7th Luxembourg report also notes that allergic reactions or other results of repeated or long term exposure also need to be considered.

## **5. Risk assessment**

### **5.1 Need for risk assessment**

The need for risk assessments to be made to ensure compliance with the essential health and safety requirements is referred to in many European Council Directives. In particular, it is not only a requirement of Directive 92/104/EEC (the Extractive Industries Directive) but also of Directive 98/37/EC (the Consolidated Machinery Safety Directive) and of Directive 94/9/EC (the Explosive Atmospheres - ATEX Directive). All three of these Directives are applicable to mines.

The risk, or probable rate of occurrence of a hazard and the degree of harm that the hazard may cause, will vary depending upon the particular circumstances of the application or site of application. Depending upon the risks judged to be pertinent, the measures taken to ensure a satisfactory level of safety may also vary.

The Risk Assessment should be carried out using the procedures set out in British Standard BS EN 1050:1997 "Safety of Machinery - Principles of risk assessment"

### **5.2 Reduction of risk**

BS EN 1050:1997 provides guidance on the achievement of conditions which will indicate that the risk reduction objectives have been achieved and the risk reduction process can be concluded.

Two of the conditions are particularly relevant,

- a) elimination of the hazard or reduction of the risk by design, by the elimination of sources of ignition, or by the substitution of less hazardous materials or substances;
- b) other safety measures of a type which, by experience, provides a safe situation.

The determination of what is “less hazardous” is achieved by subjecting fluids to accepted tests, the results of which give some quantitative measure of their fire resistance and hygiene properties. Information on the accepted test methods is given in Section 3 and Appendices B and C. The importance of applying the results of experience to the risk assessment procedure cannot be over stressed. Substantial experience of the safe use of fire-resistant fluids underground and in other hazardous applications, and with the use of other safety measures is available. This document makes use of this experience to provide guidance on the requirements that may be needed for safe operation. The suitability of a fluid for any particular application should be assessed in the light of experience of use in the equipment concerned.

The fire resistance of fluids may vary widely, depending on fluid type and composition. The risk assessment should therefore consider whether secondary safety measures, in conjunction with, or instead of, certain test requirements might be needed to provide a satisfactory operational safety level. The level of fire resistance of a fluid, i.e. the primary safety measure, considered to be necessary may depend on whether secondary safety devices, e.g. fire extinguishers, are in use at the site of application.

The fire resistance of some hydraulic fluids may change with time or with operational service. Fire-resistant fluids rely on their water content or their chemical composition and physical properties to provide fire resistance. Circumstances that could result in the reduction of the water content below its original value or chemical or physical changes in the fluid could produce impaired fire resistance. Such situations could arise through persistent high temperatures, fluid spillage where evaporation or separation could occur or breakdown of fluid chemical properties during use. No specific test has been designated to cater for these situations, which should be addressed through regular fluid monitoring and good housekeeping procedures.

The risk assessment should assess the likelihood of the fire resistance of a product being reduced in the application for which it is intended (see 3.3.2 and Figure 1). Guidance is given in Appendix A of this document on the types of fire-resistant fluid available and their properties, on operational factors associated with their suitability for service and on measures that may be taken to maintain their operational suitability.

The fire, and hygiene hazards listed in Section 4 above should not be taken as the only factors which may compromise operational safety. Other aspects such as environmental requirements may have to be considered and these may require additional or alternative safety precautions to be employed. Guidance on the assessment of environmental aspects is given in Part VI of the 7th Luxembourg Report.

## **6. References**

This document makes reference to ISO and CEN specifications wherever possible and also to European Commission document “Requirements and Tests applicable to Fire-Resistant Hydraulic Fluids used for Power Transmission and Control (Hydrostatic and Hydrodynamic) Seventh Edition” Document No 4746/10/91 EN April 1994 (the 7th Luxembourg Report). Other types of document to which reference is made include

CETOP (European Oil Hydraulic and Pneumatic Committee) and British Coal specifications.

For dated references, subsequent amendments to or revisions of any of these publications apply to this document only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

Mines Miscellaneous Health and Safety Provisions Regulations 1995

European Council Directive 92/104/EEC (the Extractive Industries Directive)

ISO 12922 – Specification for fire-resistant hydraulic fluids (in preparation)

British Coal Specification 463:1981 “Emulsifying Oils for Dilute Emulsions for Hydraulic Purposes”

British Coal Specification 570:1981 “Fire Resistant Fluids for use in Machinery and Hydraulic Equipment (Safety requirements and physical characteristics only)”.

ISO 2592:1973, Petroleum products – Determination of flash and fire points - Cleveland open cup method.

ISO 15029-1 Determination of spray ignition characteristics of fire-resistant fluids Part 1: Hollow cone nozzle method (in preparation)

ISO 15029-2 Determination of spray ignition characteristics of fire-resistant fluids Part 2: Stabilised flame heat release method.

BS EN ISO 14935:1999 Petroleum and related products - Determination of wick flame persistence of fire-resistant fluids

CETOP RP65H 1994 “Manifold Ignition Test for Fire-resistant Fluids”

European Commission document “Requirements and Tests applicable to Fire-Resistant Hydraulic Fluids used for Power Transmission and Control (Hydrostatic and Hydrodynamic) Seventh Edition” Document No 4746/10/91 EN April 1994

Chemicals (Hazard Information and Packaging) Regulations 1994

Control of Substances Hazardous to Health Regulations 1994

Notification of New Substances Regulations 1993

European Council Directive 98/37/EC (the Consolidated Machinery Safety Directive)

European Council Directive 94/9/EC (the Explosive Atmospheres - ATEX Directive)

BS EN 1050:1997 “Safety of Machinery - Principles of risk assessment”

ISO 6743-4 Lubricants, industrial oils and related products (class L) – Classification – Part 4: Family H (Hydraulic systems)(revision of ISO 6743-4:1982 in preparation)

ISO 3448:1982, Industrial liquid lubricants – ISO viscosity classification

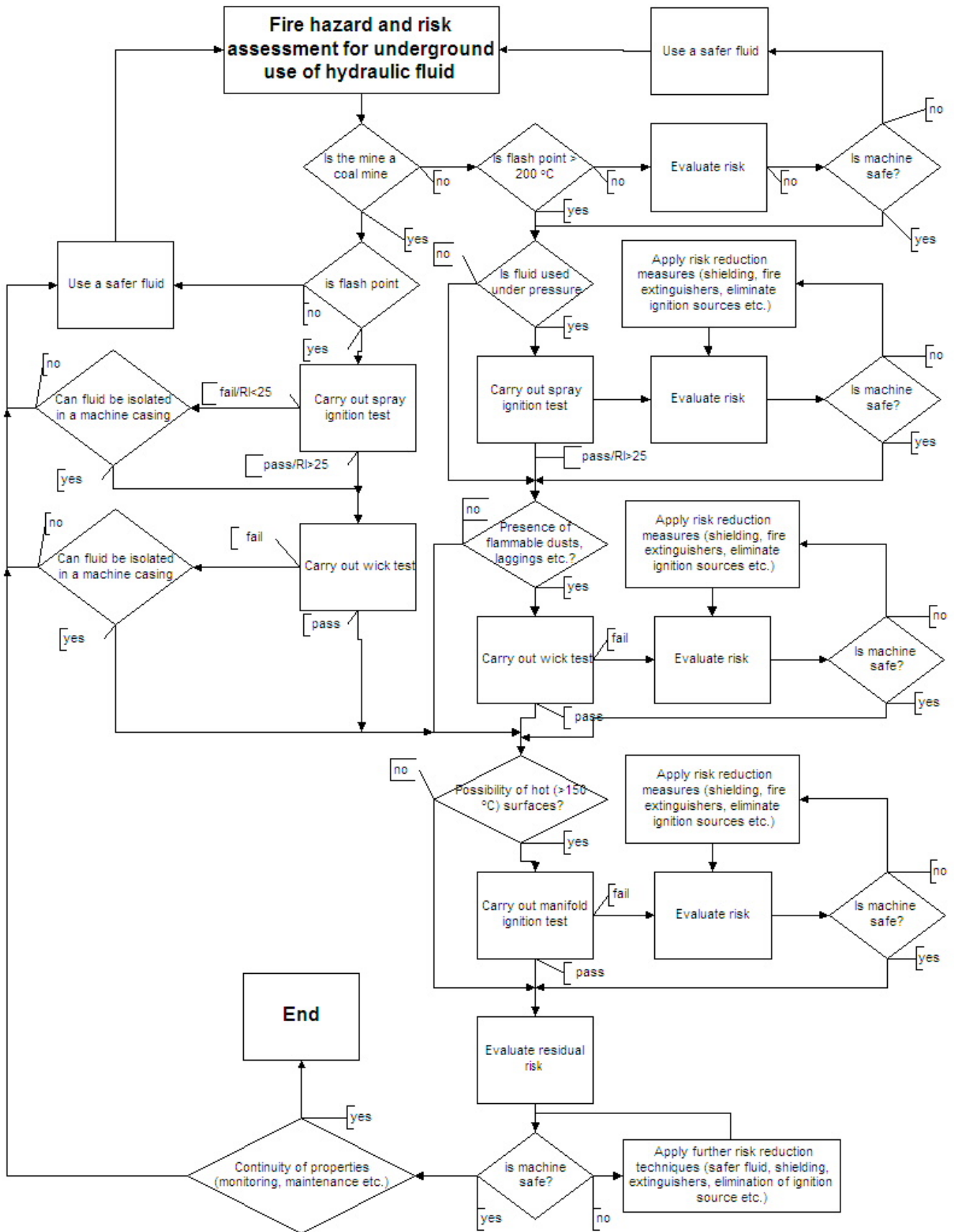
European Council Directive 91/339/EEC (the Dangerous Substances Directive)

European Council Directive 92/69/EEC (classification, packaging and labelling of dangerous substances), also European Council Directives 96/54/EC (the 22nd adaption of Council directive 67/548/EEC) and 98/73/EC (the 24th adaption of Council directive 67/548/EEC), both relating to classification, packaging and labelling of dangerous substances

Approved Code of Practice to the Chemicals (Hazard Information and Packaging) Regulations (the CHIP ACOP on Test Methods).

Mines (Substances Hazardous to Health) Regulations 1996

**Appendix D to this Document lists standards and test methods that are technically equivalent or technically similar.**



**Figure 1** Flowchart summarising fire hazard and risk assessment process

# Appendix A

## Classification of fire-resistant fluids, their properties and uses

### A1 Introduction

Fire-resistant fluids achieve their fire resistance either because they contain water or because their chemical composition confers fire resistance. Because the water content and chemical composition of fire-resistant fluids vary, so also do levels of fire resistance and other properties. This Appendix gives guidance on the types of fire-resistant fluids available for use, the properties and characteristics they possess and on their maintenance.

### A2 Classification

The following table lists the principal classifications of fire-resistant fluids to be found in ISO 6743-4, their compositions and applications.

Type	Composition	Typical applications and operating temperature range
HFAE** (see Note 1)	Oil-in-water emulsions Emulsifying oil content less than 20% by weight and typically in the range 1 to 5 % by weight.	Hydraulic mine roof supports Operating temperature range 5 to 55oC
HFAS**	Synthetic aqueous solutions Concentrate content less than 20% by weight and typically 1 to 5 % by weight.	Hydraulic mine roof supports Operating temperature range 5 to 55oC
HFB** and HFB**L T	Water-in-oil emulsions. Mineral oil content approximately 60% by weight, "LT" designation indicates emulsions that are stable at low temperatures	Hydrostatic systems Operating temperature range 5 to 60oC
HFC**	Aqueous monomer and polymer polyglycol solutions. Water content not less than 35 % by weight	Hydrostatic systems Operating temperature range -20 to 60oC
HFDR**	Phosphate ester based fluids	Hydrodynamic couplings, operating temperature up to 150oC  Hydrostatic transmissions, operating temperature range 10 to 70oC
HFDU** (see Note 2)	Water-free fluids based on chemical compounds other than phosphate esters and chlorinated hydrocarbons	Hydrostatic systems

**Note 1** The designation \*\* in the table denotes the viscosity grade according to ISO 3448. The grade is given by the kinematic viscosity at 40oC at the mid-point of each of the ISO viscosity bands, each of which has a tolerance of 10 % on the mid-point viscosity. Thus, for example, an invert emulsion might be designated HFB 68 LT,

indicating that the fluid has a viscosity which falls within a band that is 10 % of 68 mm<sup>2</sup>/s at 40°C, and that the fluid has good low temperature stability. The viscosity grades most commonly encountered in mining applications are 32, 46, 68 and 100.

**Note 2.** Fluids that fall within the HFDU class are of necessity defined imprecisely. Their chemical compositions could vary widely as could their fire resistance properties, which may change in use. Particular care needs to be taken to determine whether individual fluids will meet the fire resistance requirements listed in Sections 3.1 and 3.2 and continue to meet these requirements in service (see 3.3.2).

### **A3 Fluids not permitted**

Two classes of HFD fluid referred to as HFDS and HFDT were previously produced and used in hydraulic systems. These products were water-free fluids based on chlorinated hydrocarbons and on mixtures of phosphate esters and chlorinated hydrocarbons respectively. European Council Directive 91/339/EEC classified chlorinated hydrocarbons and products containing them, as dangerous substances and their provision and use was made illegal. These fluids are therefore not available for use. Phosphate esters themselves are not classified as dangerous substances.

### **A4 Properties and characteristics**

#### **A4.1 HFA fluids**

The HFAE and HFAS fluids most often contain in the region of 95 % of water and are therefore very fire resistant. The viscosity of these fluids is very close to that of water, although there are some HFA products termed “High Water Based Fluids” that have higher viscosities, in some cases similar to those of hydraulic mineral oils, and lower water contents e.g. 70 to 80%. Subjecting HFA fluids to the fire-resistance tests described in Section 3 and Appendix B is not generally required. Fire resistance is provided by maintaining the water content specified by the manufacturer.

HFA fluids are generally poor lubricants, although their lubrication properties are much superior to those of raw water. Because of the low viscosities, leakage rates can be high.

A common problem with HFA fluids is bacterial and/or fungal infestation via the make-up water or from residual fluid in the hydraulic system. Bacterial infestation is often very difficult to remove completely. Some HFA products are formulated to contain a biocide to seek to prevent this infestation, but the use of biocides may have adverse implications for the environment.

The amount of dissolved solids, and particularly the hardness of the make-up water for HFA fluids, can affect their stability. The fluids are formulated to produce stable emulsions over particular ranges of water hardness. The UK coal mining industry has used two ranges of water hardness, namely softer waters that have hardnesses up to 250 ppm calcium carbonate equivalent, and harder waters that have hardnesses between 250 and 750 ppm calcium carbonate equivalent. Products have been formulated to be compatible with these particular ranges of hardness. When used with make-up waters outside these ranges the fluids may not be stable and may not provide adequate corrosion protection.

The emulsifiers used in these products tend to be chemically active species and care needs to be taken to ensure that the fluids are compatible with rubbers and plastics used as sealing elements and in similar components.

#### **A4.2 HFB fluids**

HFB fluids, which are referred to as invert emulsions, have mineral oil as the continuous phase with water emulsified into it. The water content is usually around 40% and some of this, perhaps 5%, may be substituted by glycols to provide low temperature stability (the "LT" grades.)

The fire resistance of invert emulsions is provided by the water content and it is therefore vital that the water content be monitored in service to ensure that the correct level is maintained. Operation at excessive temperatures may lead to unacceptable water loss and consequent reduction in fire resistance.

Although the bulk viscosity of HFB fluids is similar to that of the mineral oil products they replace e.g. ISO 68 or 100, the lubricating properties of HFB's are significantly inferior to mineral oils. One of the reasons for this is that the viscosity of these fluids tends to reduce at high rates of shear to that of the mineral oil phase. Because of the nature of HFB fluids the viscosity of the oil phase is low and results in low film thickness in bearing contacts with reduced bearing life.

The emulsifiers used in these products tend to be chemically active species and care needs to be taken to ensure that the fluids are compatible with rubbers and plastics used as sealing elements and similar components.

HFB fluids used in the coal mining industry are formulated to pass the spray ignition test in Section 3.1.2 of the 7th Luxembourg Report (the "UK" test) and the Wick test to the method given in BS EN ISO 14935. They will not generally, however, pass the rather more severe "Community of Six" spray test in 3.1.1 of the 7th Luxembourg Report. (See Appendix B Section B2.2)

HFB fluids may also suffer from bacterial and/or fungal infestation.

#### **A4.3 HFC fluids**

HFC fluids are true solutions of water and mono- and polyglycols. They are able to operate at lower temperatures than HFB fluids, but in the past have been found to be inferior to HFB's in their lubricating properties.

Fire resistance of HFC fluids is influenced by the water content and it is therefore vital that the water content be monitored in service to ensure that the correct level is maintained. Operation at excessive temperatures may lead to unacceptable water loss and consequent reduction in fire resistance.

The fire resistance of HFC fluids is generally superior to that of HFB's and they are usually formulated to pass the "Community of Six" spray ignition test given in 3.1.1 of the 7th Luxembourg Report as well as the Wick test to the method given in BS EN ISO 14935.

#### **A4.4 HFD fluids**

The various fluids classified as HFD do not contain water and obtain their fire resistance from their chemical formulation. They are generally much better lubricants than HFB or HFC fluids, but their fire resistance can vary widely. This variation arises in part because of the diversity in possible formulations that can be classified as HFD.

The two classes HFDS and HFDT are no longer supplied because of health, hygiene and environmental concerns which lead to their use being made illegal by the European Council (see Directive 91/339/EEC)

HFDR fluids that have been used widely in the UK coal mining industry, both in hydrostatic and hydrodynamic systems are formulated to pass the spray ignition test in Section 3.1.2 of the 7th Luxembourg Report (the "UK test") and the Wick test to the method given in BS EN ISO 14935.

Although concern has been expressed in the past regarding neurotoxicity of certain impurities that can be found in phosphate esters, products that are currently in use readily meet the toxicity requirements in the Luxembourg Report. These substances are not classified as hazardous under the COSHH Regulations. Part IV of the 7th Luxembourg Report contains a test method and requirements for examining the neurotoxic effect of phosphate ester fluids.

Phosphate esters tend to be more chemically active than mineral oils and care needs to be taken to ensure that the fluids are compatible with rubbers and plastics used in hoses, sealing elements and similar products.

The HFDU classification is specific only in its exclusion of phosphate ester and chlorinated hydrocarbon-containing products, and therefore embraces fluids of any other composition. The performance in terms of fire resistance of fluids in this category might, therefore, be expected to vary considerably from fluid to fluid and particular care needs to be taken with these fluids to establish their properties and the continuity of these properties during use on an individual basis.

## **Appendix B**

### **Fire test methods**

#### **B1 Introduction**

The ease with which fluids ignite and their combustion characteristics in particular situations can be measured by means of well-established laboratory test methods. This appendix provides information on the test methods appropriate to the basic fire hazards listed in Section 4.1 that should be used to determine compliance with this document and on alternative methods that are available. The list is not intended to be exhaustive, but covers the methods most commonly used. In general tests are of two types: those which deal with the likelihood of ignition and those which can be used to quantify the consequences of burning fluid. The range of available tests does not cover all possible release scenarios and ignition sources.

**It is important to realise that no one test can provide a full assessment of the fire resistance of a fluid and consideration must be given to a range of tests that are appropriate to the hazards perceived for a particular application.**

#### **B2 Test methods**

##### **B2.1 Ignition of flammable vapours**

The ease with which vapours above a heated fluid become ignited is measured by the “flash point”. The flash point is the lowest temperature at which the application of a test flame directed into a cup containing the fluid causes the vapour above the fluid to ignite. It is indirectly a measure of both the volatility of the fluid and the flammability of the volatiles contained therein. It is mainly of value for quality control and regulatory purposes. Flash point is also used to categorise fluids as “flammable”, “highly flammable” or “extremely flammable” under the Chemical (Hazards, Information and Packaging for Supply) Regulations.

A number of methods have been used for the determination of flash points of various petroleum-based products, including

- Flash Point by the Abel Apparatus - IP test methods 33 and 170
- Flash Point by the Setaflash Closed Tester - IP 303
- Flash Point by the Pensky-Martens Closed Tester - ISO 2719 and IP 34
- Flash and Fire points by means of the Cleveland Open Cup - ISO 2592
- Flash Point (Open) and Fire Point by means of the Pensky-Martens Apparatus IP 35

The Cleveland Open Cup method for the determination of flash point contained in ISO 2592 should be used for the assessment of the hazard from flammable vapours for the purposes of this Document. Care should be taken to avoid confusion over the method of test used to determine flash point since the various tests will not necessarily give the same result.

##### **B2.2 Ignition of a spray**

Three methods of test, all of which involve attempting to ignite a spray of fluid under defined conditions, have been used to assess the fire hazard caused by the ignition of a spray of fluid. All three are detailed in the 7th Luxembourg Report as methods 3.1.1, 3.1.2 and 3.1.3. Method 3.1.2 is identical to ISO 15029 Part 1 and method 3.1.3 is identical to ISO 15029 Part 2.

Both method 3.1.1 and method 3.1.2 (the “Community of Six” and the “United Kingdom” tests respectively) provide a pass or fail criterion. The “Community of Six” test differs from the “United Kingdom” test in terms of the nozzle used to produce the spray, the details of the ignition procedure and the criteria for passing the test. In the “Community of Six” test the pass/fail criteria involve both ignition of the fluid and the length of the flame produced by ignition. In the “United Kingdom” test persistence of burning is the criterion. Fluids which will pass one test will not necessarily pass the other.

The third test in the 7th Luxembourg Report is the “Stabilised flame heat release test”, (section 3.1.3) which was produced to try to harmonise results from the two tests described above. In this test a steady input of heat from a pilot burner flame is again used to ignite a defined spray of the fluid, but in this case the ignitability of the fluid is measured by the amount of heat it releases. The temperature differences between the air entering the test chamber and the exhaust gases are measured:-

- • without fluid discharging from the spray nozzle; and
- • with fluid discharging from the spray nozzle.

The temperature difference is a measure of the heat released. An ignitability factor is calculated on the basis of the relationship between the temperature differences i.e. the heat release, (a) when only the burner is ignited and (b) when the fluid spray is ignited by the burner. The measurements are made when the flame produced by the burning spray has stabilised. In addition it is possible to measure smoke production and flame length. In contrast to the other two methods, therefore, the “Stabilised flame heat release test” quantifies fire hazard giving the user the opportunity to use the information generated in a risk assessment procedure and to choose a level of fire resistance suitable for his application. Performance in the “Stabilised flame heat release” test is not necessarily related to performance in the other two tests.

Test methods 3.1.2 and 3.1.3 in the 7th Luxembourg Report (ISO 15029 Parts 1 and 2) should be used for the assessment of the hazard caused by the ignition of a spray of fluid for the purposes of this Document.

### **B2.3 Fluid soaking into absorbent material**

BS EN ISO 14935 (the Wick Test) has been found to be adequate to measure the fire resistance of fluids when soaked into absorbent or flammable materials and the extent to which the fluids will propagate fire. The test is also described in section 3.2.1 of the 7th Luxembourg Report and in British Coal Specification 570. Originally this test was carried out using an asbestos wick, but this has been replaced by alumino-silicate tape. In this test a flame is applied to a wick that has been soaked in the fluid under test under defined conditions and the persistence of burning after the removal of the flame is measured.

The test described in section 3.2.2 of the 7th Luxembourg Report the “Determination of flame propagation in a fluid/coal dust mixture” has also been used for the assessment of this hazard. In this test 37.5 cc of test fluid is mixed with 75 g of a specifically defined

coal dust, the mixture is placed in an appropriate container to form a test piece 150 mm long, the mixture ignited and the length of propagation is observed.

Correlation between the Wick test and the coal dust test is good, but a pass in one cannot invariably be taken to indicate a pass in the other.

BS EN ISO 14935 should be used to assess the hazard produced by fluids when soaked into absorbent or flammable materials for the purposes of this Document.

#### B2.4 Ignition from a Hot Surface

CETOP RP65H 1994 "Manifold Ignition Test for Fire-resistant Fluids" has been found suitable to assess this hazard. In this test fluid is poured on to a tube heated to 704°C and observations are made as to whether the fluid:-

- flashes or burns on the tube, but does not after dripping from the tube,
- does not flash or burn on the tube, but does after dripping from the tube,
- does not flash or burn on the tube or after dripping from the tube.

This test should be used for the purposes of this Document.

## **Appendix C**

### **Hygiene tests and acceptance criteria**

#### **C1. Introduction**

Part IV of the 7th Luxembourg Report details procedures and test methods designed to establish whether a fluid represents a health hazard in the conditions under which it is likely to be used in a mine. It provides a methodology for assessing fluids based on:-

- a review of all available toxicological data on the ingredients in the fluids or formed in the fluids by reaction
- examination of the results of tests carried out in conformity with the Report when it has been found necessary to carry these out because of inadequate data;
- examination of reports on the health of persons who have been in contact with the fluid during manufacture or testing.

#### **C1.1 Review of available data**

The review of the available toxicological data may include the performance of and experience with fluids of similar chemical composition. Since the 7th Luxembourg Report was produced the legislation regarding health and safety and dangerous substances has been updated, notably by the various issues of the CHIP Regulations and the extension of the COSHH regulations underground. In some cases the requirements of these regulations and of the Notification of New Substances Regulations provide a means of obtaining the data required for assessment and may make elements of the testing described in the Report superfluous. Sections C2 to C7 of this Appendix give examples of how information supplied under CHIP may be used to determine the scores that are needed for the 7th Luxembourg Report, and how COSHH or other information can assist in the evaluation of a fluid.

#### **C1.2 Test procedures**

The test procedures in the 7th Luxembourg Report are invoked when data from other sources are inadequate. The test methods are based on those described in European Council Directive 92/69/EEC (Classification, Packaging and Labelling of Dangerous Substances), but other methods regarded as more stringent and more specific to exposure conditions in mines are included. Directive 92/69/EEC has been revised by Directives 96/54/EC and 98/73/EC and is expected to be further revised on a regular basis by the issuing of new Directives. It is adopted in the UK as the Approved Code of Practice to the Chemicals (Hazard Information and Packaging) Regulations 1994 (the CHIP ACOP on Test Methods).

The test methods are designed to provide scores for each hazard, which at certain levels disqualify the product. If the product is not so disqualified a weighting factor for the particular class of fluid is applied for each test and the scores are summed to provide a value to be set against a pass/fail score. In the majority of cases it should be possible to use the CHIP and COSHH Regulations to give similar or superior information.

### **C1.3 Effects of long term exposure**

Part IV of the 7th Luxembourg Report warns that the test methods that it contains cannot predict whether a fluid will produce effects such as allergic reactions (sensitisation) or other effects produced by repeated or long term exposure, and indicates that monitoring for these effects may be needed. Other test methods that are not contained in the Report may be available to examine potential for allergic reactions (sensitisation) or other long term effects.

### **C2. Oral toxicity**

The 7th Luxembourg Report states that wherever possible the acute oral toxicity LD50 (i.e. the dose which causes the death of 50% of animals used for the tests) for in-use concentrations should be determined from existing data. Where specific studies are thought necessary or where the data is inadequate the determination of oral toxicity is performed on young adults rats to a specified procedure or to the procedure described in the Annex to Directive 92/69/EEC.

The CHIP Regulations provide for three element classes - Very Toxic, Toxic and Harmful. Risk phrases R28, R25 and R22 respectively apply to the oral risks. Otherwise the substance is unclassified in this respect.

Fluids classed as Toxic or Very Toxic under CHIP would score too highly in the 7th Luxembourg Report tests to be accepted and would not need to be examined for scoring for other categories. Fluids classed as Harmful would score 2, unclassified fluids 0. A clear classification position under CHIP will render further testing unnecessary for this category.

### **C3. Skin irritation**

The 7th Luxembourg Report states that because of the possibility of extended and widespread skin contact and the general unavailability of washing facilities underground, a special skin irritation protocol is needed, involving tests on rabbits.

Fluids classed as corrosive (“causing burns” and “causing severe burns”) under the CHIP regulations would score too highly in the 7th Luxembourg Report tests to be accepted and would not need to be examined for scoring for other categories.

The CHIP Regulations provide a classification of Irritant (Risk phrase R38) for fluids which score a certain figure. Fluids classed as irritating to skin score 2 or more. Exact figures are not directly obtainable from the CHIP classification and would have to be obtained from the supplier.

### **C4. Eye irritation**

The 7th Luxembourg Report gives a test method for assessing this hazard based on tests on rabbits, examining the effects on the cornea, the iris and the conjunctiva. Such results could be obtainable from knowledge of the properties of the known constituents of a fluid which the supplier could make available, otherwise the Luxembourg Report requires specific testing.

Fluids attracting the CHIP risk phrase R41 ('risk of serious damage to eyes') would score too highly in the 7th Luxembourg Report tests to be accepted and would not need to be examined for scoring for other categories.

The CHIP Regulations provide a classification of Irritant, Risk phrase R36 ('irritating to eyes') for substances. Exact figures are not directly obtainable from the CHIP classification and would have to be obtained from the supplier.

### **C5. Aerosol toxicity**

This hazard results from the escape of fluids under high pressure into the breathing zone of underground workers. The 7th Luxembourg Report requires ill-effects of aerosols (cold for HFA, HFB and HFC and both hot and cold for HFD) to be assessed from specific tests on rats, considering such matters as effects on respiration and general behaviour as well as mortality, whereas CHIP sets a standard based on the acute inhalation toxicity (LC50).

Occupational exposure limits are set for a number of aerosols in EH40 (Occupational Exposure Limits for use with COSHH) or have been determined by manufacturers. As the 7th Luxembourg Report quotes a figure of 5 to 10 mg/1 as concentrations that may be achieved in the field, knowledge of the composition of each hydraulic fluid could allow a concentration of each component to be calculated and compared with the standard. Fluids could be accepted or rejected on that basis, but care would be needed in this instance to allow for the fact that the method of test in the 7th Luxembourg Report requires an exposure time of one hour and relates to an accidental release situation, whereas occupational exposure limits are often established in relation to daily, repeated exposure under controlled conditions.

The assessment made under COSHH for hydraulic fluids could also be based on actual monitoring studies of simulated escape situations for fluids maintained under high pressures.

### **C6. Thermal decomposition**

The 7th Luxembourg Report gives a method of testing for HFB, HFC and HFD fluids (other than HFDU fluids) in which rats are subjected to the substances produced when the fluid is projected on to a plate heated to 700°C. For HFDU fluids that have an ignition temperature below 700°C the plate is heated to a temperature just below the ignition temperature of the fluid. The method of evaluation of the results is similar to that of the aerosol toxicity tests.

The CHIP Regulations are not attuned to this hazard, although the decomposition products themselves may be listed in the Approved Supply List. Analysis of atmospheres produced by the combustion of fluids under simulated circumstances would give precise information on breakdown products which could then be assessed in terms of a COSHH assessment for hydraulic fluids. This could take into account such factors as ventilation, the provision of early warning systems and the availability of personal protective equipment.

### **C7. Neurotoxicity (phosphate esters only)**

This aspect applies to HFD fluids containing phosphate esters. The phosphate esters used in UK mines were originally derived from coal tar residues and contained variable

levels of neurotoxic compounds e.g. tri-ortho cresyl phosphate. In recent years production of phosphate esters has been by a synthetic process, resulting in much better defined fluids with impurity levels at least an order of magnitude lower than those produced from coal tar residues. Because of the low levels of neurotoxic phosphates in synthetic fluids it could be argued that only synthetic fluids should be accepted.

The 7th Luxembourg Report recommends animal testing of each production batch, to determine whether the batch is neurotoxic. Work was carried out by British Coal to establish a correlation between the levels of neurotoxic impurities determined by chemical analysis and the results of animal tests, so that phosphate esters could be accepted on the results of chemical analysis. Where a correlation has been established between levels of neurotoxic phosphates obtained by chemical analysis and the results of the tests for neurotoxicity in the 7th Luxembourg Report, then chemical analysis for neurotoxic phosphates may be used as the basis for acceptance or rejection of fluids. This obviates the need for neurotoxicity testing on live animals.

## Appendix D

### Equivalent or corresponding specifications

The following table gives references to specification produced by various organisations that are either technically equivalent or are very similar and could be quoted as alternatives.

Property	ISO	BS	7 <sup>th</sup> Luxembourg	Institute of Petroleum	CETO P	British Coal
Spray ignition (UK test)	15029-1	As ISO	3.1.2	n/a	RP55H	570:19 81
Spray ignition ("Buxton" test)	15029-2	As ISO	3.1.3	n/a	RP55H	n/a
Wick test	14935:1999	As ISO	3.2.1	n/a	RP66H	570:19 81
Flash point (Cleveland open cup)	2592:1973	4689:1980	n/a	36	n/a	n/a
Manifold ignition	n/a	n/a	n/a	n/a	RP65H	n/a
Viscosity	3104 1994	2000 Part 71:1990	5.1.2	71	n/a	n/a
Viscosity Classification	3448:1992	4231:1992	n/a	n/a	n/a	n/a

## **Appendix E**

### **Drafting and consultation**

The following were involved in the drafting of this document

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Dr S Fairhurst	Head of Toxicology Unit, HSE
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Mr P J McGuinness	HM Inspector of Mechanical Engineering in Mines, HSE
Mr D Phillips	FMC Corporation (UK) Ltd
Mr M Williams	HM Inspector of Mechanical Engineering in Mines, HSE
Dr E D Yardley	CERBERUS (Mining Acceptance Services) Ltd

The following organisations were consulted:-

Association of British Mining Equipment Companies  
British Gypsum Ltd  
Castrol Oils Ltd  
Deep Mines Coal Industry Advisory Committee  
Eimco (GB) Ltd  
Fuchs Lubricants (UK) plc  
Health and Safety Executive  
Houghton Vaughan plc  
Institute of Mining and Metallurgy  
Laporte Minerals  
Mining Association of the United Kingdom  
Quaker Chemical Ltd  
RJB Mining (UK) Ltd  
Shell UK Oil Products Ltd  
Webster Schaeff and Co

## **Appendix F**

### **Regulation 8 of the mines miscellaneous health and safety provisions regulations 1995**

For the convenience of the reader of this document Regulation 8 is reproduced below.

**8(1) Subject to the provisions of paragraph (2) the manager of every mine shall ensure so far as is reasonably practicable that only hydraulic fluids which are both difficult to ignite and satisfy any specifications relating to fire resistance and hygiene approved for the purposes of this regulation are used at the mine.**

**8(2) Where it is not reasonably practicable to use hydraulic fluids which satisfy the requirements of paragraph (1) the manager shall ensure appropriate action is taken to avoid any increased risk of fire resulting from the use of the hydraulic fluid.**